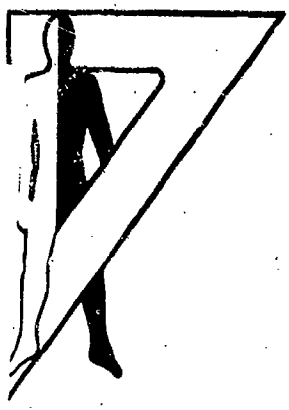


AD

Technical Memorandum 7-85

AN INFORMATION ANALYSIS OF THE SHORT-RANGE AIR DEFENSE FIRE UNIT

Jon J. Fallesen

April 1985
AMCMS Code 612716.H700011

Approved for public release; distribution is unlimited.

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Memorandum 7-85	2. GOVT ACCESSION NO.: A157378
3. RECIPIENT'S CATALOG NUMBER:	
4. TITLE (and Subtitle): AN INFORMATION ANALYSIS OF THE SHORT-RANGE AIR DEFENSE FIRE UNIT	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Jon J. Fallesen	8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. ARMY HUMAN ENGINEERING LABORATORY, Aberdeen Proving Ground, MD 21005-5001	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS Code 612716.H700011
11. CONTROLLING OFFICE NAME AND ADDRESS:	12. REPORT DATE: April 1985
	13. NUMBER OF PAGES: 53
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Human Factors
Short-Range Air Defense (SHORAD)
Information Overload
Equipment Design Survey
Information Requirements
Command and Control (C^2)
STINGER

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In response to a request by the Joint Forward Area Air Defense (JFAAD) activity, the information requirements of the short-range air defense (SHORAD) fire unit were analyzed and are addressed in this report. The analysis considers several information taxonomies to aid in the systematic evaluation of the information items. The analysis was based on the availability and opportunity to use the information, the relative priority of the information, the timeliness or rate of recurrence, and the capability of the soldier to use the information. Survey data, which were

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

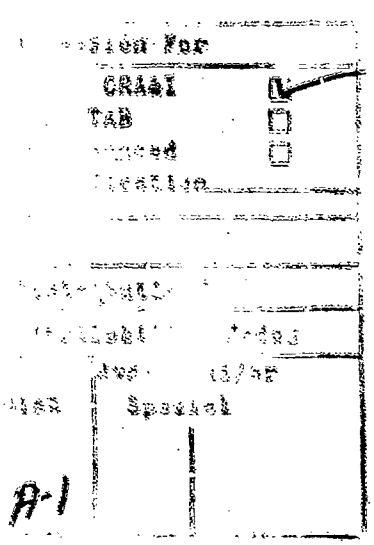
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

collected from two SHORAD battalions, were used in the human factors engineering (HFE) judgments on information needs, priority, and timeliness. A procedural event analysis was used to determine the opportunity to use the information.

The human factors engineering judgments led to a listing of four general categories of information elements. The categories and proposed minimal SHORAD information requirements are (1) mission order: weapons control status, state of alert, primary target line (PTL) and sector of fire, communications-electronics operation instructions (CEOI), petroleum, oils, and lubricants (POL) and ammunition supply points, threat, defended asset, unit supported and friendly element locations; (2) air defense warning; (3) early warning air track data: position, identification, heading, and raid size; and (4) engagement air track data: highest priority threat, range, positive identification, weapon information, and flight profile. Some of these elements require other data to base a decision or a perception. For example, positive identification of air track requires direct vision, an identification friend or foe (IFF) response, or hostile-acts criteria. Originator-supplied keywords:

The limitations of the approach are discussed. The advantages and disadvantages of opinion surveys, as well as information theory, signal detection theory, and mental workload methodology, have been discussed in relation to verifying the information requirements. The research approach taken by the Air Defense Team is indicated as an alternate verification approach whereby information requirements will be a by-product of "part-task" and integrated soldier-machine interface studies.

to field ?



AMCMS Code 612716.H700011 Technical Memorandum 7-85

AN INFORMATION ANALYSIS OF THE SHORT-RANGE AIR DEFENSE FIRE UNIT

Jon J. Fallesen

April 1985

APPROVED:
JOHN D. WEISZ
Director
U.S. Army Human Engineering Laboratory

U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005-5001

ACKNOWLEDGMENTS

The author would like to thank Mr. Kirk Jones, Scientific Technical Advisor, Joint Forward Area Air Defense (JFAAD) Test, for suggesting the need for this work, and also SFC James Bevins for assisting in the compilation of background material. This work was supported in part by JFAAD, Ft. Bliss, TX.

CONTENTS

AN INFORMATION ANALYSIS OF THE SHORT-RANGE AIR DEFENSE FIRE UNIT

INTRODUCTION

A major concern of the soldier-machine interface (SMI) is the information processing capabilities of the individual. In other words, how well can information be sensed, gathered, organized, understood, acted upon, and subsequent decisions be made and executed. In the face of technologically sophisticated systems, the equipment operator is forced to process more information at increased rates compared to earlier systems. On the modern battlefield as weapon systems become more advanced and mission capabilities increase, the potential peak human information processing requirements may surpass the capabilities of the soldier. The information processing demands can be decreased by automating previously performed manual tasks and by carefully considering human factors.

OBJECTIVE

This report addresses the information needs of the short-range air defense (SHORAD) fire unit. Its objective is to propose a framework for a minimal list of information requirements based on (1) information availability and the opportunity to use it, (2) information priority, (3) timeliness (rate of recurrence), and (4) the capability of the SHORAD soldier to use the information.

BACKGROUND

The Joint Forward Area Air Defense (JFAAD) activity has recognized the problem of providing the correct information to the soldier and requested the assistance of the U.S. Army Human Engineering Laboratory (USAHEL) in addressing it.

The information requirements of short-range air defense command and control (SHORAD C^2) are greater than comparative echelons of other combat elements based on the tasks required of its systems and mission. These more stringent conditions include a three-dimensional target space; visual target identification, compounded by the possible approach of the target from any direction; and the lethality, speed, altitude, and maneuverability of the target threat. Other conditions include remote sources of sensor data (as opposed to colocated); air defense artillery (ADA) elements being one of the first objects of attack; the requirement for positive hostile identification prior to engagement; multiple liaisons for command control; and Air Force command of the airspace and weapons control status.

One approach to eliminate potential overload problems relies on the premise that the information requirements of the soldier should be kept to the minimum necessary to effectively support his mission. It is poor practice to design a system to present the soldier with all available information. It is challenging to design the system and its operation based on information needs and timeliness, and the soldier's desires, capabilities, and limitations (i.e., an approach based on users' needs and characteristics rather than on hardware capabilities).

Generalized human performance consequences during information overload include: the increase of errors, the increase in time as a result of filtering the information, and the use of some queueing strategy. In the case of errors and increased time, performance may be degraded below acceptable limits. The filtering of information will compete with other requirements of information processing like decision making. The queueing of information will also require mental processing and may place information in an inappropriate location in the queue.

There is a sizable subdiscipline of human factors which is concerned with the study of measuring mental workload and ways to predict what the workload level will be under various circumstances (Moray, 1979; Ogden, Levine, & Eisner, 1979; Williges & Wierwille, 1979). Once measurement techniques are successfully developed for an application (which can be a difficult and time-consuming effort), two questions about predicting workload arise: (1) Can the operator adequately perform the task under various conditions, including extreme environmental stress or system operation? or (2) Can additional requirements be placed on the operator without negatively affecting overall performance, i.e., what spare capacity is available? As such, a mental workload approach is most suitable after system design to test and evaluate the capability to use information. This technique is not used typically to address information requirements.

Information requirements are not often addressed completely. One indirect approach is to rely on a thorough definition of the task along with an analyst's judgment. A task analysis and an operational sequence diagram are useful tools for defining the task. Seldom are information requirements specified separately from a specific system design, which makes it difficult to take results from one area of the combined arms and apply them to another.

METHODOLOGY

The lack of an established methodology for addressing the information needs of the combat soldier was a difficulty experienced during this effort and required that a methodology be developed. For the most part, the approach used an untried technique which cannot be confirmed without a systematic and time-consuming series of data collection. Although the approach is subjective, it brings together relevant sources of information in a systematic manner to enhance judgment. The methodology is depicted generally in Figure 1. First, a tentative information taxonomy was developed as a framework for information concerns of the SHORAD unit (Step 1, Figure 1). (See Appendix A for the background development.)

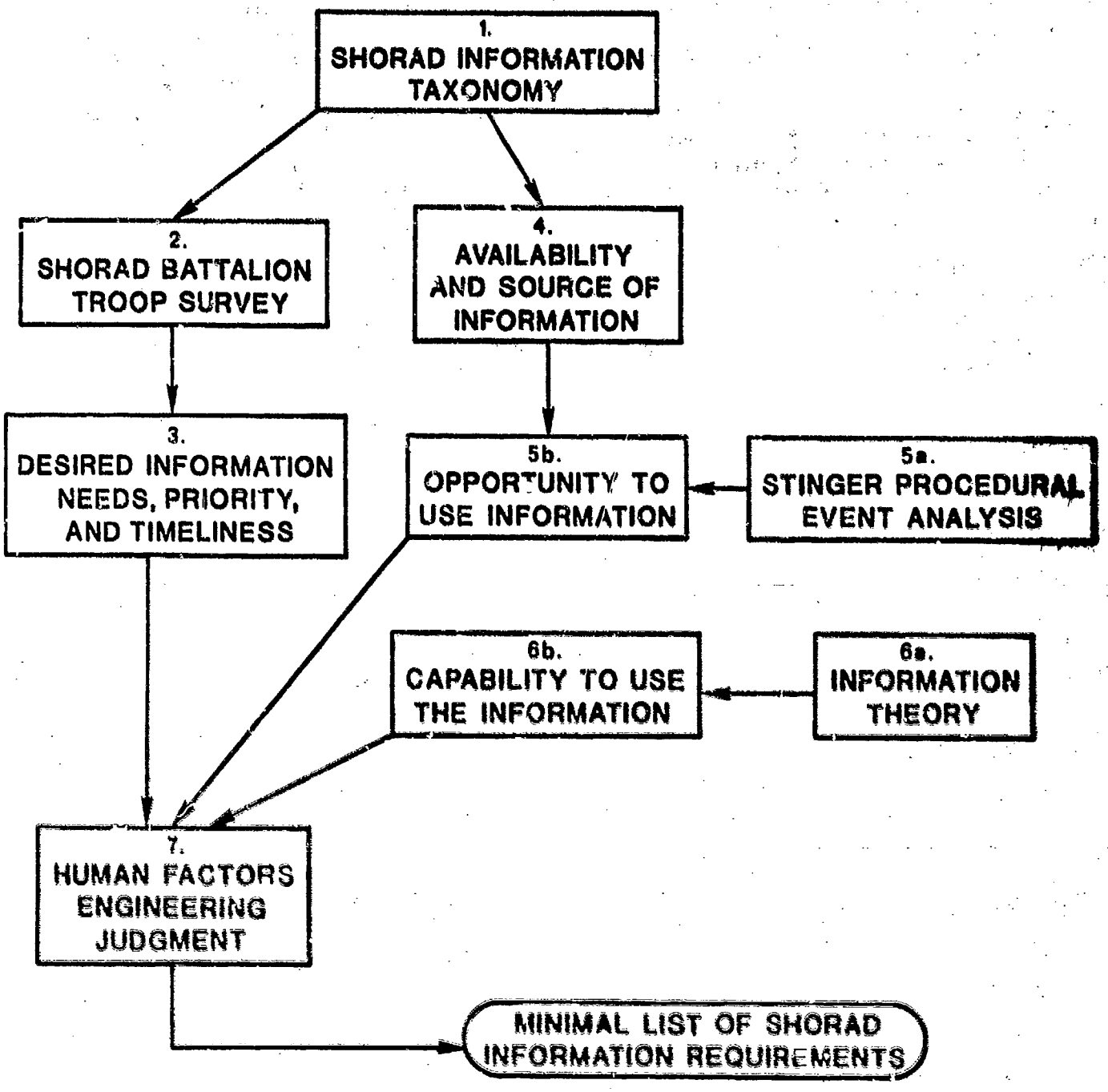


Figure 1. Methodology for addressing the information needs of the SHORAD fire unit.

From the taxonomy, the methodology followed two branches. One branch used the taxonomy to survey a sample of SHORAD fire unit personnel to determine information requested to complete their mission successfully (Step 2). These survey results also provided an indication of the priority and timeliness of the information (Step 3). The second branch was to consider the information which could be available to the soldier during an engagement (Step 4). Some information is clearly not of concern at the fire unit, and some information is not available or not completely reliable. The output from this human factors engineering (HFE) analysis was used in a comparison with the fire unit's "opportunity" to use the information (Step 5b) based on a procedural event analysis (Step 5a). A STINGER team was used as an example fire unit in this and all other portions of the methodology requiring a specific system or crew.

Another element was used in the methodology. The STINGER team's "capability" to use the information (Step 6b), which is the most speculative aspect of this methodology, was used in the HFE judgment to address the information needs. The applicability of information theory was addressed regarding human information processing capabilities (Step 6a). The results of the information survey, the STINGER team's "opportunity" to use the information, and the estimation of the STINGER team's "capability" to use the information were compared to make recommendations (Step 7).

This methodology has the following constraints: 1) fire unit information requirements are not static but dynamic, i.e., they have multiple dependencies (e.g., scenario, mission, weapon, crew, weather, etc.), 2) information timeliness is limited to a generalized case because of multiple factors, 3) priority is addressed in a general case, and 4) the capability to use the information is dependent on the individual and differences between individuals. The recommendations on information needs should be considered with these constraints in mind.

INFORMATION ANALYSIS

SHORAD Troop Survey

The information taxonomy was used in part as the basis for developing of a SHORAD troop survey. A survey of SHORAD platoons was conducted at Ft. Hood, TX in July 1984. Platoons from the 1st Cavalry Division and the 2nd Armored Division were surveyed regarding their experience and preferences for information and design formats for the developmental SHORAD C^2 system. Three versions of a questionnaire were developed based on questions derived from concepts from the SHORAD C^2 System Specification (ADCCS PO, 1984), the Human Factors Engineering Statement for the SHORAD C^2 System (USAHEL-AD, 1984), and the Air Defense Team Research Plan for SHORAD C^2 (internal working paper). Vulcan, Redeye, and Chaparral platoons from each division completed a fire unit version of the questionnaire (see Appendix B). Two forward area alerting radar (FAAR) platoons, one from each division completed a FAAR version, and personnel from the ADA battalion tactical

operations center (TOC) completed a battalion (bn) version. Table 1 gives details on the respondents' characteristics. The sampling technique did not stratify on the basis of experience. A wide range of SHORAD experience was represented, from the new recruit to the career noncommissioned officer. As such, the survey is a sample of the user population, not a sample of "experts." A full report of the survey will be available subsequent to the release of this report.

Two questions directly pertain to the information analysis being described in this report. The fire unit version of the questionnaire is reproduced in Appendix B. Question 9 is a check list asking for the fire unit platoon personnel to check any of the listed items of information which must be known to complete the combat mission and to place a question mark by any item which was not understood. Question 10 asked the respondents to select and rank order the five most important items from the list in 9 and to indicate how often the information would be used.

The responses to question 9 tended to indicate that most of the listed information items were felt to be important. There were no frequencies lower than 47 percent (i.e., 42/90) for the individual information items. The lowest frequency was associated with the item of firing doctrine. (Twelve percent of the respondents indicated that they did not understand what this item meant.) Thirty-two of the thirty-seven items in question 9 were considered to be necessary information by 66 percent or more of the respondents (Table 2), suggesting that a majority of the respondents desired as much information as possible. The results on desired needs, priorities, and timeliness are summarized in the following sections.

Priority of Information Items

The rankings of the group responses can be considered to result in a general priority scheme for the purposes of Step 3 in Figure 1. The fire unit rankings of the items in question 9 appear in Table 2. In question 10, respondents were asked to select the five most important information items (from those listed in question 9) and to rank order them in importance. The frequency results from this question were computed as a weighted sum. The first through fifth rankings for each information item were tabulated and summed with a weighting of 5 given to the most important item, 4 to the second, etc. These weighted sums were rank ordered for the 37 information items in question 10 (Table 2) and compare favorably to the ranks of frequency responses for question 9 (Table 2). Of the top four items, no difference in ordering occurred between the two questions. A Spearman's Rho correlation between the ranks in questions 9 and 10 (Table 2) was .8429, which is significant at the .0001 level, meaning that a positive correlation greater than chance exists.

TABLE 1

Profile of Respondents' Characteristics

Questionnaire Version	Platoon	MOS[a]	Number of Respondents	Number from Division 1st	Number from Division 2nd	Number in Grade/Skill Level O1-O2	Number in Grade/Skill Level E1-E4	Number in Grade/Skill Level E5	Number in Grade/Skill Level E6	Number in Grade/Skill Level E7	Average Age (yr)	Average Length of Service (yr)	Average Length of Service (mo)	Average Time in Primary MOS (yr)	Average Time in Primary MOS (mo)
Fire Unit			90	48	42	4	53	14	16	3	24.1	4	7	3	8
	Chaparral	16P	37	22	15	2	21	7	6	1	24.2	4	3	3	3
	Redeye	16S	32	11	21	0	22	4	4	2	23.2	3	10	3	5
	Vulcan	16R	21	15	6	2	10	3	6	0	25.4	5	5	4	8
FAAR		16J	26	-	-	0	16	4	5	1	25.5	5	8	3	3
Battalion		16H	12	5	7	0	2	1	5	4	30.5	9	8	8	8

[a]Military occupational specialty

TABLE 2

Ranked Frequencies of Information Items

Ranked Frequencies of Information Items in Question 9.			Ranked Frequencies of Information Items in Question 10.		
Rank	Information Item	Frequency[a]	Rank	Information Item	Weighted Frequency Sum[b]
1.5	Weapons control status (WCS)	89	1	WCS	154
1.5	Target position	89	2	Target position	152
3.5	Target identification	88	3	Target identification	123
3.5	Air defense warning	88	4	Air defense warning	121
5	Sector of fire	87	5	MOPP status	73
6.5	Target heading	85	6	Target heading	55
6.5	Hostile criteria	85	7	IFF/SIF	50
8.5	Target type	84	8.5	PTL	45
8.5	Number of rounds	84	8.5	State of alert	45
10	Identification friend or foe (IFF)/Selective identification feature (SIF)	83	10.5	Number of rounds	42
			10.5	Movement order	42
11	Raid size	82	12	Ammunition supply point	37
12.5	Primary target line (PTL)	81	13	NBC report 1-5	33
12.5	State of alert	81	14	Hostile criteria	32
14	Ammunition Supply Point	80	16	Sector of fire	31
16.5	Movement order	77	16	Raid size	31
16.5	Engagement priority	77	16	CEOI	31
18	Mission-oriented protection posture (MOPP) status	76	18.5	Enemy activity	30
			18.5	Target type	30
19	Nuclear, biological, chemical report 1-5	75	20	Target speed	24
			21.5	Map data	13
21	Rules of engagement (ROE)[c]	72	21.5	POL resupply	13
21	Defended asset	72	24	Engagement Priority	12
21	Weapons engagement zone	72	24	ROE[c]	12
23.5	Enemy activity	71	24	Weapon map location	12
	Target speed	71	26	Track designator	11
25	Warning report	69	27	Warning report	10
26.5	Communications-electronics operation instructions (CEOI)	68	28	Defended assets	9
			29.5	Kill assessment	7
			29.5	Highest priority target	7
26.5	Petroleum, oils, and lubricants resupply	68	31	Priority of assets	5
			32.5	Area of operation	4
28	Area of operation	66	32.5	Air corridors	4
29	Priority of assets	64	34.5	Battle lines	3
30	Highest priority target	63	34.5	ECM	3
31	Battle lines	61	36	Weapons engagement zone	1
32	Weapon map location	60	37	Fire doctrine	0
33	Track designator	54			
34.5	Kill assessment	48			
34.5	Electronic countermeasures (ECM)	48			
36	Air corridors	46			
37	Firing doctrine	42			

[a] There was a possible frequency of 90 respondents.

[b] There was a possible weighted frequency sum of 450 (occurring if all 90 respondents rated the same item as most important).

[c] The rules-of-engagement item was included in addition to weapons control status, state of alert, and hostile criteria to represent the collection of factors it makes up.

Target Data Priority

The target data which the SHORAD C^2 automated system proposes to process, transmit, and display, for alerting and cueing, were hypothesized (during the development of the USAHEL fire unit information list in Table 1A) to result in the order of importance in Table 3. The actual priority ranking is indicated in Table 4. The reasons for the hypothesized order follow.

Position was considered to be the most important because it indicates the presence of a track and some idea of how soon it should or could be engaged. Identification was considered to be second in importance because it further indicates whether the aircraft should be engaged. It is not of first importance because of the difficulty of determining the positive identification; many targets will be of an unknown identification. Heading and speed were reasoned to be of third importance since they indicate the engageability of the target and further refine how soon it could be engaged. Aircraft classification information was next in importance since it provides guidance on how the target is to be engaged and the time a track may be in an engagement envelope. It provides some redundancy regarding speed and identification. Raid size will affect the engagement process, e.g., in a STINGER team a notification of multiple targets would indicate that both team members should shoulder a weapon. Jamming, special track, and identification-conflict indicator are special cases of information which could impact the engagement process.

Resulting data on information items pertaining to the air track information set nearly fell in the same rank ordering as the hypothesized ordering (Tables 3 and 4). Two exceptions were the 6th and 8th rankings for the items of engagement priority and track designator. Although these items were not ranked in the hypothesized list, their rank position is logical. Another difference was that target speed was combined with target heading into one item of target velocity for the prior hypothesized ordering. The resultant ordering from question 10 for track data items corresponds quite well.

Information Timeliness (Rate of Recurrence)

As a second part to question 10, the respondents were asked to indicate how often they would use the 5 most important information elements. The categories were: continuously--every few seconds, immediately--every few minutes occasionally--every few hours, and infrequently--every few days or weeks. Table 5 shows the frequencies of timeliness by the ordered information elements. The priority rankings from the two confirming methods and timeliness data provide considerations for the human factors engineering judgment.

TABLE 3

Hypothesized Order of Importance of Target Items

1	Position (azimuth, elevation, range)
2	Identification
3	Heading and speed (speed vector)
4	Aircraft classification (i.e., wing type)
5	Raid size
6	Jamming
7	Special track
8	Identification-conflict indicator

TABLE 4

Target Data Priority List

Relative Rank	Target Data	From Table 2 Frequency	From Table 2 Rank
1	Target position	89	1.5
2	Target identification	88	3.5
3	Target heading	85	6.5
4	Target type (class)	84	8
5	Raid size	82	11
6	Engagement priority	77	16.5
7	Target speed	71	23.5
8	Track designator	54	33
9	Jamming/ECM	48	34.5

TABLE 5

Desired Timeliness of the Highest Priority Information

Rank from Table 2	Information Item	Frequency[a]	Timeliness			
			Seconds	Minutes	Hours	Days/Weeks
1	WCS	43	10	11	18	0
2	Target position	40	23	12	2	1
3	Target identification	35	18	11	1	1
4	Air defense warning	35	9	8	13	0
5	MOPP status	24	5	5	12	1
6	Target heading	18	14	4	0	0
7	IFF/SIF	18	11	3	0	2
8.5	PTL	12	6	2	4	0
8.5	State of alert	15	4	5	4	1
10.5	Number of rounds	15	2	7	4	1
10.5	Movement order	14	3	0	5	3
12	Ammunition Supply Point	18	2	1	7	5
13	NBC report 1-5	12	1	3	6	0
14	Hostile criteria	14	4	4	3	1
15	Sector of fire	10	4	0	4	0
16	Raid size	13	8	2	1	0
16	CEOI	12	1	3	3	2
18.5	Target type	11	6	5	1	0
18.5	Enemy activity	13	2	6	5	0
20	Target speed	12	7	3	2	0
21.5	Map data	5	0	2	2	1
21.5	POL resupply	5	0	0	3	2
24	Engagement priority	5	2	2	0	0
24	Rules of engagement	4	1	1	0	0
24	Weapon map location	4	0	2	1	0
26	Track designator	4	3	0	0	0
27	Warning report	4	2	1	1	0
28	Defended assets	4	1	0	2	0
29.5	Kill assessment	2	1	0	1	0
29.5	Highest priority target	3	2	1	0	0
31	Priority of assets	1	1	0	0	0
32.5	Area of operation	3	0	1	1	0
32.5	Air corridors	1	0	1	0	0
34.5	Battle lines	1	0	0	1	0
34.5	CCM	1	0	0	0	1
36	Weapons engagement zone	1	0	0	0	0
37	Firing doctrine	0	0	0	0	0

[a]The number of times the item was chosen as any one of the top 5 items of priority; the maximum possible frequency was 90.

Engagement Information Available

To fulfill Step 4 in the methodology, the information taxonomy in Table 9A was reviewed for information which was relevant to the engagement situation and which would be available in the Manual SHORAD Control System (MSCS). This stage of the analysis was generally a reductionist approach, considering the information specified in the taxonomy and determining which would directly affect the engagement situation. (It was assumed that information available in the MSCS would be available under any improved system. Additional information may be available, but it was not considered during this stage of the analysis.) The engagement information considered to be available and its source are given in Table 6. The sources include the division air defense early warning (DADEW) net, visual detection/observation, identification friend or foe (IFF), hostile acts, command (comd) net, standard operating procedures (SOPs), system indication, and proprioception.

The taxonomy from Table 9A, from which the information in Table 6 was based, is primarily founded on communications to and from the fire unit. The absence of detailed and system specific weapon information is apparent, e.g., minimal information is presented on IFF, weapon radar range data, or infrared (IR) tone. (The absence of the information indicates an incompleteness of the taxonomy in its present form.) Information which is available at the fire unit and of concern can be determined by considering a generalized sequence of engagement procedures required by a weapon system.

STINGER Procedural Event List

To conduct a more detailed analysis of information needs, the STINGER team was chosen as the fire unit for discussion purposes. Two generalized event lists are given for STINGER operation (Step 5a, Figure 1). The order of events is generalized because of the relative nature of event occurrences. Not all events will always occur nor would they necessarily occur in the "relative," chronological order which is listed. Table 7 lists the events from when a mission is received until a potential engagement situation exists. Table 8 lists the decisions and actions which the STINGER team makes once the engagement situation begins. Similar action events were used in the STINGER human factors engineering critical task analysis during the system's development (General Dynamics, 1973).

Opportunity to Use

The information elements of the engagement procedure were determined by considering the generalized event list in Table 8. The information items for Step 5b (Figure 1) were determined to be those listed in Table 9. Of these information items the first two groupings may have the greatest potential for presenting problems to the fire unit. The first general category has many different information items. The air track data may overwhelm the team by either the quantity of information in a single

TABLE 6

Engagement Information Available

Engagement Information Available	MSCS Source
Air track report	
Position	Early warning (EW) net, visual detection
Identification	EW net, IFF, visual detection, hostile act
Heading	EW net, visual observation
Wing type	EW net, visual observation
Raid size	EW net, visual observation
Speed	EW net, visual observation
Weapons control order	
Weapons control status	Command (comd) net
State of alert	Comd net
Air defense warning	Comd net
Primary target line	Comd net
Sector of fire	Comd net
Rules of engagement	Standard operating procedures (SOPs), comd net
Hostile criteria	SOPs, comd net
Weapon orientation	System indicator, visual observation, proprioception
Rounds remaining	Visual observation
Battlefield geometry	(Comd net[a])
Division boundaries	
Air corridors, zones, etc.	
Warning report	Comd net

[a]Battlefield geometry may not be transmitted to the fire unit in the MSCS.

TABLE 7

Event List of STINGER Team Procedures

Training
- Basic
- AIT
- Unit
- FMs, TMs, TCs, Crew drills
- SOPs

Past experience

Warning order
- What the mission will be
- When it is to take place
- Where it will take place
- What initial preparation to make
- When the detailed plan is expected

Accompany the section leader on reconnaissance

Receive mission
- Mission order (FM 44-18)
  - Situation
    - Information on threat and friendly forces
    - Mission and intended actions at next higher echelon and other nearby ADA units
  - Mission
    - What the unit is to do
  - Execution
    - Tactical plan to accomplish the mission
    - Tasks for each individual
  - Service support—plans for
    - Ammunition
    - Resupply
    - Casualty evacuation
    - Rations
  - Command signal
    - IFF information
    - Radio frequencies and call signs, signals and other control measures
    - Location of leader and next higher leader
- STINGER team preparations (FM 44-18-1)
  - Who supported?
  - To whom to report?
  - Call sign and frequency
  - Where is FAAR?
  - What is communications schedule?
  - Security arrangements
  - Threat
  - Weapons control status
  - State of alert
  - Mess and fuel locations
  - Sign and countersign
  - Special instructions
  - Missile resupply
  - When and where will IFF be reprogrammed?

(Continued)

TABLE 7 (CONTINUED)

Event List of STINGER Team Procedures

Movement

Request a change in position or in other orders as needed

Occupation of position
(Conceal, camouflage, fortify--ongoing)

Re-establish communications, if necessary

Ready system for action

Unload system, if necessary

Assembly, if necessary

Weapons checks (minimum)
- Battery coolant unit (BCU)
- Safety and activator, uncage and trigger
- IR window and blowout disk
- Humidity indicator
- Acquisition indicator
- IFF receptacle
- IFF interrogator, cable, and antenna

Indicate "ready for action" to section leader

Combat situation

Ready for engagement

Potential engagement situation

TABLE 8

Decisions and Actions of the STINGER Team During a Potential Engagement Situation
(FM 44-18, FM 44-18-1, TM 9-1425-429-12)

If displayed or voice-told track data are received as early warning or alerting information, then what is the track's position, identification, heading, wing type, raid size, target speed, etc.? Is it likely to intersect the area of responsibility? Is it likely to be an engageable target?

If the weapon is not already shouldered, should it be?

If the weapon is not readied, then
confirm the BCU is seated properly,
unfold the IFF antenna,
remove the front cover,
raise the sight,
and attach the IFF cable.

From which direction and when will the target unmask (i.e., first possibility of visual line of sight)?

If an object is a valid aircraft target, then begin the engagement sequence.

Point weapon and center target in reticle, continue tracking throughout.

Actuate the IFF interrogation.

What is the IFF reply?

What is the positive identification of the target (using data from the IFF, visual identification, hostile acts, EW report, etc.)?

Is the aircraft crossing or incoming/outgoing?

What is the wing type of the aircraft?

Is aircraft within range (use a time-count rule for jets on crossing; use a range-ring estimate for jets incoming/outgoing; propeller/aircraft are within the range when weapon is activated), hostile identification made, and IR acquisition lock-on obtained?

(Continued)

TABLE 8 (CONTINUED)

Decisions and Actions of the STINGER Team During a Potential Engagement Situation
(FM 44-18, FM 44-18-1, TM 9-1425-429-12)

Should the target be engaged?

If not, should others be alerted by radio communication?

Should the weapon be activated? (45-second life of BCU with 1 activation per).

If so, operate the safety and actuator (3-5 seconds of weapon warm-up).

Has a distinct IR acquisition tone been achieved?

Uncage IR seeker.

Test for seeker lock-on.

Has seeker lock-on been achieved (uncaging)?

For superelevation lead, should the aircraft be placed in the left, center, or right reticle?

Insert superelevation and lead angle.

Discriminate the strength of the IR acquisition tone.

Firing: Have all requirements been met--tone, smooth track, and within engagement zone?

Hold breath.

Actuate the fire trigger.

Continue tracking through missile launch.

If exhaust plume persists, move away from plume.

Post engagement

Remove the BCU within 3 minutes.

Should the team move to an alternate position?

Should additional weapons be readied?

Should post-engagement reports be made?

TABLE 9

Information Items Used During a STINGER Engagement Sequence

Air track data—includes both early warning and directly observed information
Rules of engagement, including weapons control orders, hostile criteria, sector of fire, primary target line, and/or battlefield geometry[a]
IFF procedures and interrogation response
Positive identification (based on IFF reply, visual identification, hostile acts, EW report, etc.)
Flight profile (crossing, incoming, or outgoing)
~~Range estimation (in or out of range)~~
Indication of proper weapon activation
Acquisition signal
Lock-on signal and relative strength
Superelevation and lead angles

[a]These are obtained prior to engagement but have direct impact on procedures and decisions during engagement.

air track report or by the number of different air track reports. The second category requires the team to rely on memory for several of the procedural-related items, e.g., rules of engagement and airspace restrictions. The items in this category are used in making an identification determination and an engagement decision. Some of the specific data for these items may go back quite some time in the historical event line, e.g., the definition of weapons tight and the specification of hostile acts are taught during advanced individual training (AIT) (Table 7). Also, the interrelationship between the rules of engagement (ROE) and other doctrinal aspects create a difficult decision-making situation.

Human Capabilities

Application of Information Theory

Information theory, derived from a mathematical communications theory, has application for assessing human capabilities to use information (Shannon & Weaver, 1949) (Step 6a, Figure 1). In applications to psychological study, the human is viewed as an element in a communication channel. Information is seen as a statistical quantity that describes how much information is conveyed from source to receiver when a given message or stimulus is delivered. Besides this typical view of information in information theory, two other levels are considered. The second involves the meaning of the information which is transmitted. The third level deals with the effectiveness of information or how it is utilized once it has been received and understood. The first level is limited with the successful transmission of the message or perception of stimuli, the second with the successful interpretation of the message or stimuli, and the third with the appropriate application or use of the information.

The theory of information also considers channel capacity. The capacity of a communication channel is considered to be the maximum possible rate of transmission. In behavioral applications, the greater interest is in the amount of information which the human can process. This is not a quantity that is measured directly but is inferred as a maximum possible rate. The inference depends on the way the information is coded (Fitts & Posner, 1967). In human engineering and equipment design, information transmission capacity has been used to determine the maximum number and types of codes possible within a presentation modality (e.g., signal loudness has five consistently discriminable categories), the maximum rate of information presentation, or the maximum rate of operator decision making (Van Cott & Warrick, 1972). The channel capacity of five discriminable codes is equivalent to 2.3 bits (binary units) of information. The channel capacity of unidimensional stimuli generally does not exceed 3.5 bits or about 11 categories. The perceptual discriminations which we make daily among hundreds of categories are possible because of the multidimensionality of stimuli (e.g., voices or faces).

Several attempts have been made to determine the upper limit of human information processing. Van Cott and Warrick state that, "Unfortunately, there is no single, simple upper limit; rather, it varies from task to task" (p. 29). For the response system, the limit appears to range from about 3 to 9 bits per second. The upper rate for reading is about 43 bits per second, which is the fastest of those listed by Van Cott and Warrick. In general, people have no fixed limit at the rate at which information is transmitted. Differences exist because of different stimulus-response codes and different amounts of learning (Fitts & Posner).

The difficulty in applying the information theory concepts to the engagement tasks of the SHORAD fire unit is partially because the subtasks have complex interactions. The expected probabilities of the individual stimuli and responses are equally difficult to define. The technique has some potential merit, but it was considered insufficient for this level of analysis to make the necessary assumptions on event interactions and probabilities.

Military Occupational Specialty (MOS) 16S Skills and Qualifications

The qualifications of the 16S MOS are indicated in Table 10. These qualifications are minimum combined requirements for entry into the 16S MOS series. Skill level for the gunner (MOS code 16S10) is level 1, and for the team chief (MOS code 16S20) it is a level 2.

The physical profile considers six factors which have been designated PULHES. The factors are P--physical capacity or stamina, U--upper extremities, L--lower extremities, H--hearing and ear, E--eyes, and S--psychiatric. Four numerical designations are used to reflect different levels of functional capacity. A designation of 1 indicates a high level of medical fitness and a 2 indicates that an individual meets entry standards but possesses some medical or physical condition which may impose some limitations. Designation 3 or 4 is reserved for more severe limitations and special cases. The MOS 16S physical profile for eyes indicates a requirement for excellent visual acuity.

The Armed Services Vocational Aptitude Battery (ASVAB) is used to establish mental qualifications for enlistment and selection of applicants for particular occupational systems. The aptitude test has subcategories in the following areas: word knowledge, coding speed, arithmetic reasoning, tool knowledge, space perception, mechanical comprehension, shop information, automotive information, and electronic information. For the MOS 16S, a qualifying score in the aptitude area of Operator Food (OF) is emphasized.

These considerations can be used as data in the assessment of the capability to use the information (Step 4b, Figure 1). Further discussion of these capabilities follows per Step 7 of the methodology, human factors engineering judgment.

TABLE 10

Qualifications for Initial Award of MOS 16S (HQ, DA, 1984)

A physical demands rating of very heavy
A physical profile of 222211
Minimum height of 64 inches
Distance vision correctable to 20/20 without multifocal lenses
Normal color vision
A qualifying score in aptitude area Operator Food (OF)
A security clearance of CONFIDENTIAL

DISCUSSION

By completing the analyses and comparing the various tables, the following observations can be made (Step 7, Figure 1). Given sufficient advance notification and assuming the fire team is not "busy" (i.e., team is "ready for action" and is not currently in a potential engagement situation), they have an opportunity to use as many information items on air tracks as are available. The air track items considered are target position, early warning identification, heading, wing type and speed. To have successful engagements, the STINGER team needs advance notification of an air threat. Shouldering the weapon and making final assembly actions take about 10 seconds (Chaiken, 1976). One major determination of the STINGER HFE task analysis was that advance notification is almost essential to have the weapon shouldered and readied in time to complete engagement activities within the weapon frontal engagement zone (General Dynamics, 1973).

The collective desired priority of information from the Ft. Hood survey is given in Table 2. For the information items, almost 80 percent (71/90) of the respondents requested position, identification, heading, wing type, raid size and speed, as well as the engagement priority (see Table 2). The timeliness (i.e., rate of recurrent use) of the information was requested to be either in seconds or minutes. For the six target items combined, there were 76 requests for updates to be in seconds, 37 requests for updates to be in minutes, and 9 requests for the updates to be in hours or days, the latter which appears quite unrealistic. There was a total of 122 timeliness ratings available for the combination of the six items, indicating about a 93-percent ([76+37]/122) request rate for timeliness in seconds or minutes.

Various considerations were made to generate a list of information requirements. The list of minimal SHORAD fire unit information requirements is presented in Table 11. Under mission and early warning air track data, the information items are listed in relative order of priority. Under the engagement air track data, the information assumes that the track is within detection range and items are listed in the general order of usage.

One critical aspect of this evaluation which has not been previously considered is the quantity of tracks which should be presented to the fire units. The quantity of tracks is directly related to the information theory concept of channel capacity. Under a separate effort, the Air Defense Team has addressed this issue. The resulting conclusion was that seldom would a fire unit have more than 13 aircraft within a 10-km radius of its position. The design limitation of up to 15 simultaneous tracks should be displayed, if there is a highest priority track indication (XMCO, 1984). The priority indicator should serve as an immediate cue to the operator to single out that track. (Blinking of the track symbol is the recommended coding for the priority indication, DOD-STD-1477, 1983).

TABLE 11

Minimal SHORAD Information Requirements

Mission order
Weapons control status
State of alert
PTL and sector of fire
Communications procedures, CEOI
POL/Ammunition supply points
Threat, defended asset, unit supported, friendly element location
Air defense warning
Early warning air track data
Position
Identification
Heading
Raid Size
Engagement air track data
Highest priority threat
Range (in or out of weapon range)
Positive identification (based on any available source)
Weapon information (activation, acquisition, lock-on)
Flight profile (incoming/outgoing, crossing)

As indicated previously, the information is highly dependent on many situational factors. One factor which may have critical importance is the percentage of unknown and friendly tracks during battle. If past tracks have been predominantly of one identification during a series of past engagement situations, then this will affect the expectation and perception of later identifications. If the percentage of friendly tracks has been and is currently close to zero, then the fire unit personnel might venture to take a riskier approach to all engagements, i.e., they may relax the criteria they personally use to make their decisions. On the other hand, a soldier may take a more conservative approach and have increased expectations of friendly aircraft if no friends have been in the area.

One approach to study the variable decision process may come from signal detection theory (Tanner & Swets, 1954; Deatherage, 1972). Signal detection theory has applications for evaluating differences between systems as well as among observers. The approach takes into account the probability of correct recognition and the false alarm rate at the same time. "Signal-to-noise" ratios are determined under a set of circumstances, and plots of receiver operating characteristics are made to determine the response bias of the observer or the system. The theory was developed to address the question of the detection of a signal in the presence of noise, and it is unclear whether the approach can address the SHORAD identification process. The three categories of identification (viz., hostile, friend, or unknown), rather than the simpler case of signal versus noise and the multiple factors which go into the "positive" identification process, would be more complicated than "traditional" signal detection. The decision-making behavior of individuals is highly variable. One way to obviate the potential problems this inherent variability characteristic has is to provide reliable track data from sensors. Until an improved sensor is fielded, the reliability and availability of track data are tenuous.

In the meantime, suggestions for reducing the amount of track data for the Enhanced MSCS voice-tell DADEW net have been made. Because of the results of the HELDADS-I study which indicated that the Air Battle Management Operations Center (ABMOC) introduces delays, errors, and loss of information in the transmission of track data to the fire units, there is a need to modify the ABMOC operations (Fallesen, Smyth, & Blackmer, 1983). One of three suggestions which has been made reduces the length (through the removal of content) and format of the SHORAD track messages (Fallesen, 1984). The modified versions of the track messages were developed to have simplified wording (e.g., the use of "New Track" in place of "Initial Track, Initial Track"), and the information items were changed to contain only the following: (1) the type of track message, (2) the identification, only if it is different from unknown, (3) the position, and (4) the track designator.

Those items which are most likely to overload the fire unit during an engagement are (1) excessive early warning air track information unused because of ongoing procedures and decisions, (2) excessive time in a "battle station" state of alert when it could be relaxed, or (3) excessive numbers of conditional criteria for engagement, i.e., rules of engagement, varying due to battlefield geometry, sector of fire, or excessive criteria for hostile acts. Excessive air track information can stem from too many track reports or too much information contained in the report. The specific information processing "channel capacity" was not computed because of the complexity of the data relative to other applications of information theory, the continuous nature of the items and related difficulties in determining probability of event occurrences. Complicating factors for using multiple engagement criteria are the load on recall and the speed stress of performing in a fast-moving battlefield situation.

An early notification to the approximate position at track acquisition has been shown to increase visual detection ranges, however a combination of weapons control orders and an air defense warning indicating the imminence of attack may be sufficient information in some cases. At least, that has been the opinion of some of the Army (Fallesen, 1982). The belief held by some is that as long as a fire unit has an assigned primary target line, search sector, air defense warning of red (or yellow), and a weapons control order, they will be able to succeed in their mission and that specific cueing level target data are not required. This is contrary to some who contend that alerting and cueing data are needed on specific targets. There is some objective evidence to support the contention that data of cueing accuracy improve target detection. If position information is given with a fair degree of precision (i.e., a range window of 1 km and 10 degrees in azimuth), there is an operational gain of about 15 seconds or 700 meters over an alert-only condition for small, fairly slow-moving targets (viz., OH-58 with a 1-meter cross section, traveling about 90 knots) (Fallesen, Kurtz, & Fry, 1982). The contention that PTL, air defense warning, and weapons control orders are sufficient is an oversimplification of the combat conditions which are affecting the operations and tasks.

RECOMMENDATIONS

The findings presented here are based on survey data and analytical judgments. There is a lack of alternative techniques which could be used to cross-validate the determinations. One method to validate and extend the conclusions is to conduct additional interviews and surveys of "expert" practitioners and commanders. The surveys could attempt to refine the knowledge about the information taxonomy, procedures of information usage, and ultimately the information requirements. The subjectivity of this surveyed approach, as well as that conducted at Ft. Hood, is both a strength and a weakness. It is worthwhile to obtain the collective judgments and desires of the applicable population, but subjective data may not necessarily have a strong correlation with true performance outcomes.

One means of addressing information requirements is to apply information theory to the measurement of information usage and apply mental workload methodology to predict information overload. The use of information theory, workload methodology, and signal detection theory in addressing the applied nature of SHORAD fire unit information requirements would take considerable theoretical and practical work to perform evaluations under "realistic" situations, yet with the criterion of maintaining experimental control.

An alternate approach, which is more applied but less direct in addressing the information requirements issues, is one that the Air Defense Team has taken. Data to address the requirements issue will be obtained indirectly through "part-task" studies of the performance of gunner crews with prototype display equipment. Subjective opinions of the equipment operators will be collected and will provide additional information to that collected during the Ft. Hood survey which was limited to conceptual evaluations. The intent of the proposed studies at the level of the fire unit is to determine how individual information items which could be presented through an automated SHORAD C^2 system (ADCCS 90, 1984) are best presented to the individual. Questions of presence or absence of information, timeliness, quantity, priority, and format will be addressed to see what particular presentation formats will enhance or degrade typical effectiveness measures, like range of target detection.

Studies are being planned to evaluate alerting modes, display alerting formats, cueing resolution, initialization of the display device, and the effect of symbolic landmarks. An analytical effort is being conducted to determine the quantity of targets to display, and follow-on efforts will consider the information modality (e.g., through-the-sight display vs. audible display vs. man-portable computer display). The "part-task" evaluations will lend to the consideration of information requirements and to recommendations for an integrated design. The objective is for results from the partial display studies to provide predictions about integrated design and system performance, and to refine methodology so further closure can be obtained on information requirements. For now, the proposed SHORAD fire unit information requirements are suggested to include the items in Table II under the categories of mission order, air defense warning, early warning air track data, and engagement air track data.

REFERENCES

Air Defense Command and Control Systems Project Office (ADCCS PO) (1984). SHORAD C^2 system specification (MIS 34585). Redstone Arsenal, AL: Author.

Benel, R. A. (1983). SHORAD command and control: Information requirements analysis (Essex Corp Draft Interim Technical Report). (Available from Jon Fallesen, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD.)

Chaiken, G. (1976). STINGER human factors engineering final report (Technical Memorandum 25-76). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

Deatherage, B. H. (1972). Auditory and other sensory forms of information presentation. In H. P. Van Cott & R. G. Kinkade (Eds.), Human engineering guide to equipment design (pp. 123-160). Washington, DC: U.S. Government Printing Office.

Department of Defense (1983). Military standard: Symbol for Army air defence system displays (metric) (DOD-STD-1477). Washington, DC: Government Printing Office.

Fallesen, J. J. (1982). US Army Europe short-range air defense systems command and control visit (Trip report). (Available from Jon Fallesen, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD.)

Fallesen, J. J. (1984). Soldier-in-the-loop simulation for short-range air defense command and control (SHORAD C^2). In Proceedings of the 1984 Army Science Conference (pp. 283-296). Washington, DC: Office of the Deputy Chief of Staff for Research, Development, and Acquisition.

Fallesen, J. J., Kurtz, G. L., & Pry, C. A. (1982). Cueing characteristics of a proposed radar for ground-to-air target detection (Technical Memorandum 14-82). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

Fallesen, J. J., Smyth, C. C., & Blackmer, R. F. (1983). Human Engineering Laboratory division air defense systems-I (HELDADS-I): Baseline air battle management operations center (ABMOC) manual performance (Technical Memorandum 11-83). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

Fitts, P. M., & Posner, M. I. (1967). Human performance. Belmont, CA: Brooks/Cole Publishing Company.

General Dynamics, Electro Dynamic Division (1973). STINGER human factors engineering critical task analysis (U) (Classified group memorandum). Pomona, CA: Author.

Headquarters, Dept of Army (1984). Air defense artillery employment Chaparral/Vulcan/Stinger (FM 44-3). (Available from HQ TRADOC, Ft. Monroe, VA.)

Headquarters, Dept of Army (1981). Air defense artillery employment: Stinger (FM 44-18). Baltimore, MD: USA Adjutant General Publications Center.

Headquarters, Dept of Army (1984). Enlistment career management fields and military occupation specialties (Army Reg 611-201). (Available from Cdr, US Army Soldier Support Center, Alexandria, VA.)

Headquarters, Dept of Army (1984). Operator and organizational maintenance manual: Stinger air defense guided missile system (TM 9-1425-429-12). Washington, DC: Government Printing Office.

Headquarters, Dept of Army (1980). Stinger team operations (FM 44-18-1). Baltimore, MD: USA Adjutant General Publications Center.

Headquarters, Dept of Army (1977). The mechanized infantry platoon and squad (FM 7-7). Washington, DC: Government Printing Office.

Moray, N. (Ed.) (1979). Mental workload: Its theory and measurement. New York: Plenum Press.

Ogden, G. D., Levine, J. M., & Eisner, E. J. (1979). Measurement of workload by secondary tasks. Human Factors, 21(5), 529-548.

Shannon, C. E., & Weaver, W. (1949). The mathematical theory of communication. Urbana, IL: University of Illinois Press.

Tanner, W. P., & Swets, J. A. (1954). A decision-making theory of visual detection. Psychological Review, 61, 401-409.

US Army Human Engineering Laboratory, Air Defense Team (1984). Human factors engineering statement for the short-range air defense command and control (SHORAD C^2) system. (Available from Gary Kurtz, Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.)

US Army Human Engineering Laboratory, Air Defense Team (1983). Air Defense Team research plan for SHORAD C^2 (internal working paper). (Available from Jon Fallesen, Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.)

Van Cott, H. P., & Warrick, M. J. (1972). Man as a system component. In H. P. Van Cott & R. G. Kinkade (Eds.), Human engineering guide to equipment design (pp. 17-41). Washington, DC: Government Printing Office.

Williges, R. C., & Wierwille, W. W. (1979). Behavioral measures of aircrew mental workload. Human Factors, 21, 549-574.

XMCO, Inc. (1983). Final report: Personnel/equipment interfaces in development of short-range air defense command and control (SHORAD C^2) issues. McLean, VA: Author.

XMCO, Inc. (1984). Final report: Determination of the number of targets to display at the SHORAD fire unit. McLean, VA: Author.

APPENDIX A

DISCUSSION OF INFORMATION TAXONOMIES

DISCUSSION OF INFORMATION TAXONOMIES

Awareness to the importance of the information elements of SHORAD has been a recent concern of USAHEL. In the third quarter of FY83 an internal working document, Air Defense Team Research Plan for SHORAD C^2, indicated that the fire unit information requirements should be identified as the initial step in research to develop fire unit SHORAD C^2 control and display concepts. A preliminary determination, intended to be all-inclusive of fire unit information (as opposed to selective, reductive) was generated by round-table discussion.

A framework was proposed to organize the information elements as (1) target information, the threat or stimuli, (2) weapons information, the response capability or posture, and (3) the combat environment, the situation. Table 1A lists that preliminary source of information.

Table 1A

Preliminary Fire Unit Information List Developed by USAHEL-AD

Target information	
Azimuth	Number of aircraft
Elevation	Track designator
Range	ECM jamming
Speed vector	Target signature
Identification	Threat priority
Friendly aircraft	
Weapons information	
Detectability	Engageability
Primary target line	Sector of fire
Weapon orientation	Rounds remaining
Combat environment information	
Weapons control order	Frag and warning order
Air defense warning	Asset priority
Air corridors	IFF codes
CEOI	Geographic position of units
Terrain	Climates
Area of operation	Map data

Because of the critical nature of information in the development of the SHORAD C^2 system, it was necessary to have this list reviewed and enhanced. XMCO, Inc. (a technical support contractor to USAHEL in ADA operations, training, and doctrine) was tasked to review the list and provide comments. Essex, Corp. (a technical support contractor in human factors analysis) was tasked to evaluate the taxonomy, develop a new one if judged necessary and provide the detailed contents of the taxonomy.

The development or standardization of an information taxonomy was judged important for a number of reasons. A taxonomy provides a standard framework to work with to make references to, and to add and delete information as necessary. For example, in human engineering it can be used as a checklist for designing a system to display information. In modelling it can be used as a basis for developing a model and for describing its completeness. A taxonomy provides a hierarchical categorization so that relationships between elements can be seen by their location in the taxonomy. The taxonomy can generate ideas about what should be included. It organizes information elements so that different items are placed on similar levels of specificity and type.

Taxonomy Development

Additional taxonomies were provided by Essex as other potential classification schemes in a draft report (Banel, 1983). Essex contacted a number of sources to develop the taxonomies. One source was XMCO. The taxonomy resulting from that discussion was based on the echelons of SHORAD (Table 2A).

Table 2A

Essex Taxonomy I

Fire Unit	Platoon/Section
Alerting	Alerting
Cueing	Cueing
Identification	Identification
C^2	C^2
ROE	ROE
WCO	WCO
Air defense warning	Air defense warning
	Fire control/distribution
Other command information	Other command information
EMCON	EMCON
Battery	Battalion
Early warning	Early warning
Identification	Identification
C^2	Air track data
Ground battle information	C^2
Administration/logistics	Ground battle information
	Administration/logistics

A second proposed taxonomy was developed based on discussions with DOTD, Ft. Bliss, TX (Table 3A).

Table 3A

Essex Taxonomy II

Detection- Alerting, Cueing
Identification- IFF, visual
Decision- Engagement rules, doctrine/tactics
Action- Engage or not, next move

This taxonomy initially appears appealing due to its simplicity and brevity, however, it is oriented to task elemets or functions within an engagement situation and not directed to information.

The outline of a third taxonomy was proposed based on functional areas (Table 4A).

Table 4A

Essex Taxonomy III

Operations
Control of fire
ROE
Hostile criteria
Target assignment
Warning procedures
Communications
Frequencies
Administration
C^2
Logistics
Maintenance
Support
Resupply

A fourth taxonomy considered by Essex was based on the source of the network on which the information was transmitted. However, not all information is transmitted on radio networks or is unique to one radio net. Essex's final attempt was to settle for a "characterization" of the information transmission process, based on the factors in Table 3A. Before the effort was completed, the task was halted for several reasons. One of the reasons was that the ADCCS PMO released a draft specification for the SHORAD C^2 system (ADDCS PO, 1984) with their own organization of information.

TABLE 5A

Essex Taxonomy IV

Basic Factors for Characterizing Information
Message/information
Generator or source
Transmitter mode
Relay
Receiver
Display mode

As a result of the XMCO tasking for an operational-utility review of the USAHEL-AD taxonomy (Table 1A), several comments were offered. XMCO suggested detailing who needs the information, e.g., the gunner, the team leader, or the observer. Additional information was added and preliminary discrimination of the importance/priority of the information was made. They did not feel it necessary to change the basic organization of the taxonomy (Table 6A) (XMCO, 1983).

Table 6A

XMCO Modification to USAHEL-AD Taxonomy[a]

Target information			
Azimuth or coordinates	1	Data source	2
Elevation or altitude	1	Friendly aircraft location	2
Range	1	Sensor correlation	2
Identification	1	Aircraft type	2
Track designator	1	Number of aircraft	2
Threat priority	1	Target signature	2
Location	1	Detectability	2
Primary target line	1	Sensor information	2
Weapon orientation	1	Rounds remaining	2
Operability			
Engageability			
Sector of fire			
Combat environment			
Weapons control status	1	Fragment and warning order	2
Air defense warning	1	Units' geographic position	2
Asset priority	1	CEOI	2
Air corridors	1	Terrain	2
Weapons engagement zones	1	Weather	2
IFF codes	1	Area of operation	2
Firing doctrine	1	Map data	2
Rules of engagement	1		
Hostile criteria	1		
Other weapons control measures	1		

[a]The numeral "1" indicates more important and the numeral "2" indicates less important information.

ADCCS Information Sets

At the time that about 30 information sets were introduced for the SHORAD C^2 system, it was unclear why the sets were developed as they were. The elements were not organized into "chunks" of information which could enhance recall, understandability, and utility from the users' perspective. Possible reclassification schemes that were considered were based on the information in Table 7A.

Table 7A

Taxonomy Schemes for the SHORAD C^2 Information Sets

Information type (ADCCS PMO)
Procedural interaction (Essex taxonomy II)
Source/receiver/processor/request (Essex taxonomy IV)
Information transfer: Automatic/manual transmission, processing, request
Systems approach: threat, weapon, environment (USAHEL)
Information organized by echelon (Essex/XMCO taxonomy I)
Timeliness requirements
Functional: Operations, communications, administration, logistics
Target data, command orders, unit status, enemy intelligence, NBC conditions, communications security, battlefield location

It was decided that the systems approach combined with the transfer scheme would be useful as a classification scheme. Other characteristic dimensions such as timeliness could be incorporated into the taxonomy as needed. The contents of the taxonomy are based largely on the information sets for an automated system in the SHORAD C^2 System Specification (MIS 34585) (ADDCS PO, 1983).

Four high-order categories were used, modifying the previous USAHEL categories by adding information transfer. This scheme hopefully provides a logical hierarchy. Information items were rearranged. Information transfer provides a category for the request and handling of information. The weapon/unit provides a category which the user can ask about his own unit or anything applying to his team/squad. The target/threat category involves data about the air battle. The combat environment includes those situational aspects which are secondary to his operation (see Tables 8A and 9A). Appendix II of the SHORAD C^2 System Specification indicates the data elements contained in each information set.

TABLE 8A

Reclassification of the SHORAD C^2 Information Sets

(Numbers in parentheses correspond to the information set numbers in Appendix II of the SHORAD C^2 System Specification and identify it as SHORAD C^2 system specific set of information.)

I. Information transfer
   A. Data management (17)
      Unit position request (14)
      Acknowledgment/compliance

II. Weapon/unit
   A. Weapons control
      1. AD warning (1)
      2. Weapons control order (2)
   B. Mission
      1. Movement order (27)
      2. Sensor management (3)
      3. IFF/SIF reporting code (28)
      4. IFF/SIF effective code (29)
   C. Unit status
      1. Unit operational report (4)
      2. Supply and equipment status (9)
      3. Summary unit status (26)

III. Air track/threat
   A. Air track
      1. Air track report (4)
      2. Track management (15)
      3. Air track identification report (13)
      4. Kill report (6)

IV. Combat environment
   A. Battlefield geometry (8)
      1. Data link reference point (DLRP) (16)
      2. Unit position report (18)
      3. Pointer (7)
   B. Intelligence/emergency messages
      1. Warning report (19)
      2. NBC-1,2,3,4,5 (20,21,22,23,24)
      3. Effective downwind message (25)
      4. Emergency activity report (11)
      5. ECM Intercept (5)

Table 9A

Addition of Information Items to Information Sets from Table 8A

I. Information transfer (initiate requests and provide responses)
- A. Data management (17)
  - Unit position request (14)
  - Acknowledgment/compliance

II. Weapon/Unit
- A. Weapon control
  1. AD warning (1)
  2. Weapon control order (2)
  3. Other weapon control measures
- B. Mission (OPORD & FRAGO)
  1. Movement order (27)
     - a. Location
     - b. PTL
     - c. Sector of fire
     - d. Supported unit and type of support
     - e. Rules of engagement
  2. Sensor management (3) (Sgt York)
  3. IFF/SIF reporting code (28)
  4. IFF/SIF effective code (29)
- C. Unit status
  1. Unit operational report (10) (operability and engageability)
  2. Supply and equipment status (9) (rounds remaining)
  3. Summary unit status (26) (used by higher echelons)
- D. Engagement conditions
  1. Weapon orientation
  2. Concealment, detectability
  3. Rounds remaining
- E. General information
  1. SOPs, doctrine, hostile criteria, etc.

III. Target/threat
- A. Air track
  1. Air track report (4)
     - a. Position--azimuth, elevation, range, or coordinates
     - b. Identification
     - c. Heading
     - d. Wing type (classification)
     - e. Raid size
     - f. Speed
     - g. Track designator
  2. Track management (15)
  3. Air track identification report (13)
     - a. Identification
     - b. Track designator
  4. Kill report (6)
  5. ECM intercept (5) (ECM/jamming)
  6. Threat/engagement priority algorithms
     - a. Data source
     - b. Sensor correlations

IV. Combat environment
- A. Battlefield geometry (8)
  1. Battlefield geometry types (1-29), e.g., assets, air corridors, airspace management, etc.
  2. DLRP (16)
  3. Unit position report (18)
  4. Pointer (7)
- B. Intelligence/emergency messages
  1. Warning report (19)
  2. NBC-1,2,3,4,5 (20,21,22,23,24)
  3. Effective downwind message (25)
  4. Emergency activity report (11)

The system specification provides a requirement for the maximum transmission time for the information sets. The sets fall into four categories of required speed (3, 10, 30, and 64-second maximums). Table 10A indicates the ordering. Listings within categories are alphabetical.

Table 10A

Rankings of System Specification Information Sets by Transmission Speed Priority

Speed (Seconds)	Information Set
3	Air track
3	ECM
3	IFF/SIF reporting
10	Track management
30	Air defense warning
30	Air track identification
30	Pointer
30	Sensor
30	Weapons control order
64	Battlefield geography
64	Data management
64	DLRP
64	Effective downwind
64	Enemy activity report
64	IFF/SIF selective
64	Kill report
64	Movement order
64	NBC 1,2,3,4,5
64	Reporting unit position
64	Summary unit
64	Supply and equipment
64	Unit operational report
64	Warning

APPENDIX B

USAHEL SHORAD FIRE UNIT QUESTIONNAIRE

USAHEL SHORAD FIRE UNIT QUESTIONNAIRE

The United States Army Human Engineering Laboratory (USAHEL) is the Army's lead laboratory in the assessment of the soldier-equipment interface. Our purpose is to increase the efficiency and ease of use of Army materiel.

The purpose of this questionnaire is to improve a new short-range air defense command and control (SHORAD C^2) system. The laboratory is working currently on the design of this system. It is very important to find out how you think the system should work. Your honest opinion is essential.

At the fire unit, the SHORAD C^2 system will provide a device, similar to the TADDS, but with greatly improved reliability, capability, and quickness of operation. In addition to target location and identification, the system will be able to display other important information in written or map form. Also, the device will allow two-way communication by data or digital link and will replace much of the voice radio transmission currently required.

At the radar, one of the purposes of the SHORAD C^2 system will be to enter target data into the system.

At battalion, the associated devices will have many command purposes and capabilities.

Each question should be answered according to the instructions. All answers and personal data provided will be treated with regards to your privacy in accordance with the Privacy Act of 1974. If you have any questions, please ask one of the questionnaire administrators for assistance. When you have completed the questionnaire leave it with one of the administrators.

1. Length of military service: _____year(s) _____month(s)

2. Rank: _____ 3. Primary MOS: _____

4. Number of years and months in primary MOS: _____yr(s) _____month(s)

5. Additional MOSs (if any): _____ 6. Age: _____

7. Check the highest level of education completed.

_____ 11th grade or below
_____ High school diploma
_____ Graduate equivalency degree (GED)
_____ Some college
_____ College degree

8. Check all of the following which apply to you:

_____ Have played video games
_____ Frequently play video games
_____ Have taken computer course(s)
_____ Have had some experience with a home computer
_____ Have had a lot of experience with a home computer
_____ Have used a computer some of the time in my work
_____ Have used a computer much of the time in my work

9. Place a check mark by those items of information which you must know to complete your combat mission. Place a question mark "?" by any item which you do not understand.

_____ Target position
_____ Target speed
_____ Target heading
_____ Target identification
_____ Target type
_____ Kill assessment
_____ Raid size or number of aircraft
_____ Track designator
_____ Engagement priority
_____ Jamming or electronic countermeasures (ECM)
_____ Map location of weapon
_____ Number of rounds or missiles remaining
_____ Primary target line
_____ Sector of fire
_____ Area of operations
_____ Weapons control status
_____ Air defense warning
_____ Defended asset
_____ Priority of assets
_____ Air corridors
_____ Weapons engagement zone
_____ Identification friend or foe (IFF)/selective identification feature (SIF) codes
_____ Communications-electronics operation instructions (CEOI)
_____ NBC report 1-5
_____ Firing doctrine
_____ Rules of engagement
_____ Hostile criteria
_____ Enemy activity report
_____ Movement order and mission
_____ Map data, including manmade objects (roads, buildings, bridges)
_____ Battle lines and other battlefield geometry
_____ State of alert

_____ Highest priority target
_____ Warning report
_____ MOPP status
_____ Ammunition resupply point
_____ POL resupply point

10. Of those items which you checked in the question above, list the 5 most important items in the first column below. List them in order of importance with 1 being the most important, 2 being less important, and so forth.

Then for each item indicate how often you would use the information.

Items	Continuously-every few seconds	Immediately-every few minutes	Occasionally-every few hours	Infrequently-every few days or weeks
1.				
2.				
3.				
4.				
5.				

**In the following section, circle the letter of the best answer or fill in the blank.

11. How would you like to have target position represented?
    a. Target range and azimuth (compass heading)
    b. Target's geographic coordinates
    c. Other (please specify) _____
    d. Undecided

12. How would you like to have target altitude represented?
    a. An elevation in degrees
    b. An altitude category such as high, medium, or low
    c. An altitude reading (meters or feet)
    d. Other (please specify) _____
    e. Undecided

13. Which category of identification do you prefer?
    a. Hostile, friend, unknown
    b. Positive, hostile, all others
    c. Positive, friend, all others
    d. None of the above

14. How do you want targets to be classified?
    a. Jet, propeller, helicopter, missile, unknown
    b. Fixed wing, rotary wing, missile, unknown
    c. Specific targets, such as F-15, A-10, Mind-D, etc.
    d. None of the above

**Answer the following questions assuming that you have an automatic display capable of showing target position beyond visual range.

15. How would you like the air battle picture shown?
    a. The single most threatening target
    b. The 2 most threatening targets
    c. The 3 to 5 most threatening targets
    d. All hostile targets
    e. All hostile and unknown targets
    f. All targets (hostile, unknown, and friendly)
    g. Other (please specify) _____

16. If the map display device indicates the highest priority target, how often would you like the priority determined?
    a. After engagement was completed or called off
    b. Sometime before engagement is completed
    c. Every _____ seconds (fill in the blank)
    d. Undecided

17. What method of display target movement do you prefer?
    a. The target to move when the radar has updated the new position
    b. The target to move continuously as predicted from the last known position, heading, and speed
    c. Other (please specify) _____
    d. Undecided

18. Out to what range would you like to have target information supplied?
    a. 10 km
    b. 15 km
    c. 20 km
    d. 30 km
    e. 40 km
    f. Other (please specify) _____
    g. Undecided

19. Answer the following 4 statements by filling in the blanks.
    a. I want to know that a hostile or unknown target is present when it is _____km away
    b. I want to know that a friendly aircraft is present when it is is _____km away
    c. I want to know the exact position of a hostile or unknown target when it is _____km away
    d. I want to know the exact position of a friendly aircraft when it is _____km away

20. What target position accuracy do you want?
    a. To within 100 m (1/10 km)
    b. To within 500 m (1/2 km)
    c. To within 1 km
    d. To within 2 km
    e. To within 5 km
    f. Other (please specify) _____
    g. Undecided

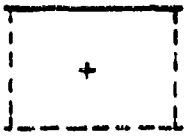
21. Which statement do you agree with the most?
    a. I want to know the positions of targets only within my primary sector of fire
    b. I want to know the positions of targets within my primary or secondary sector of fire
    c. I want to know the position of targets within or near my weapons engagement zone
    d. I want to know the position of all targets
    e. Undecided

22. How would you prefer to receive target position information from beyond visual range?
    a. From a display map
    b. From voice commands directing or pointing to the direction of the target
    c. From a display map shown within the weapon sight
    d. From tones, beeps, or other sounds directing or pointing to the direction of the target
    e. Undecided

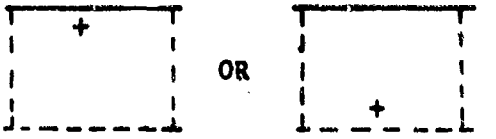
23. When a target is outside of your visual range, which would you prefer for alerting?
    a. Know only the estimated time of arrival
    b. Know only the general direction of approach
    c. Know both the estimated time of arrival and the general direction of approach
    d. Other (please specify) _____
    e. Do not want to know anything about this type of target
    f. Undecided

24. Where would you like to have your position located on the display? Refer to the diagrams found below.

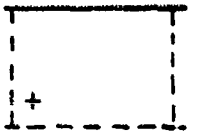
a. At center of display map



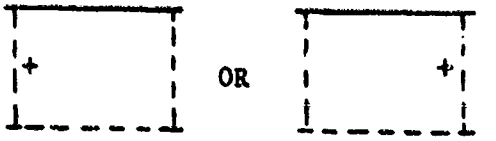
b. At top or bottom of display map



c. In corner of display map



d. At either side of display map



e. Other (please mark with an X)

f. Undecided

25. How would you like the display map to be oriented?
   a. The top of the display map should always represent north
   b. The top of the display map should always represent the PTL
   c. The top of the display map should be changeable to one of the four compass directions (east, west, north, south)
   d. The top of the display map should change direction as the display "box" is pointed to different directions
   e. Other (please specify) _____
   f. Undecided

26. About how large would you like the display area of the map device to be?
   a. 4" x 4"
   b. 6" x 6"
   c. 8" x 8"
   d. 10" x 10"
   e. Other (please specify)_____
   f. Undecided

   Explain why you chose the size you did. _____

27. What is the largest size of the map display device (including battery power source) that you would be willing to use and carry?

A. _____ inches

B. _____ inches

C. _____ inches

28. What is the maximum weight that the map display device should be?
_____ pounds

**There are different ways of broadcasting voice messages. Two examples of reporting initial, update, and scrub messages follow. Read the example and answer the following questions.

EXAMPLE A

Initial Track, Initial Track
Unknown
At Legion Three, Four
Heading Southwest
One (optional)
Jet (optional)
Track Designator: Alpha Zero One

Track Update
Alpha Zero One
Now at Kentucky Seven, Eight
Heading Southwest

Scrub Track
Alpha Zero, One

EXAMPLE B

New Track
(identification only reported for positive hostile or friendly tracks)
At Legion Three, Four
Track: Alpha Zero, One

Update
Apha Zero, One
At Kentucky Seven, Eight

Scrub
Alpha Zero, One

29. Which example would you prefer to use?
    a. Message format A
    b. Message format B
    c. Undecided

30. Which example would be quicker to broadcast over radio?
    a. Message format A
    b. Message format B
    c. No difference in quickness
    d. Undecided

31. Which example would be easier to understand?
    a. Message format A
    b. Message format B
    c. No difference in ease of understanding
    d. Undecided

32. Which example gives the information which you would rather have?
    a. Message format A
    b. Message format B
    c. No difference in information
    d. Undecided

33. What do you think is the biggest problem related to SHORAD command and control? Explain.

_____
_____
_____
_____

34. What do you think is the biggest problem related to air defense artillery (ADA)? Explain.

_____
_____
_____
_____

35. If you have any comments about this questionnaire, please explain.

_____
_____
_____
_____